

Sept. 3, 1946.

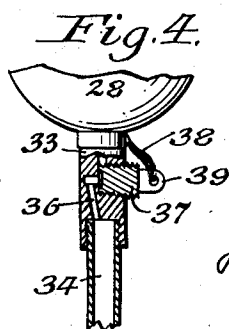
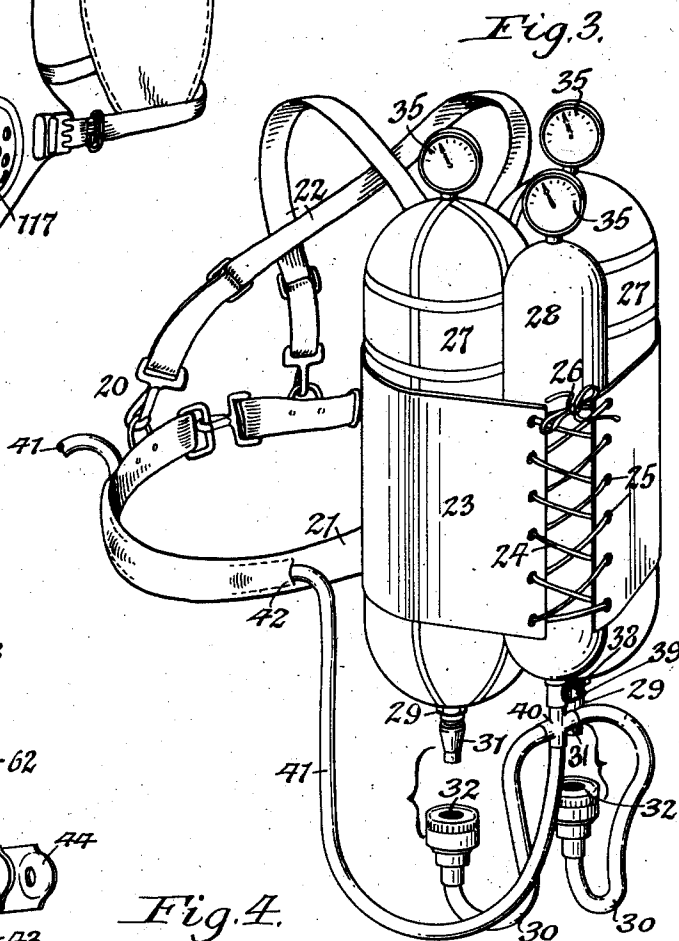
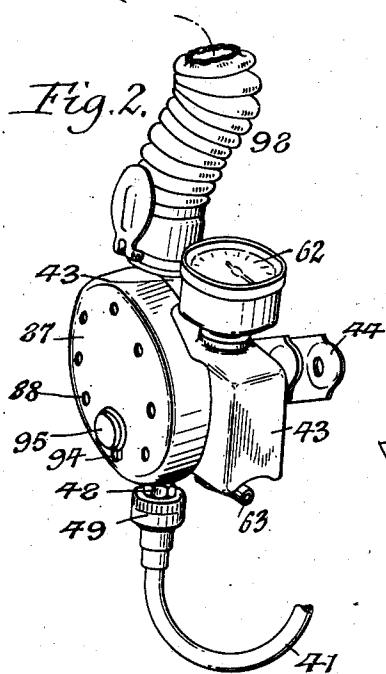
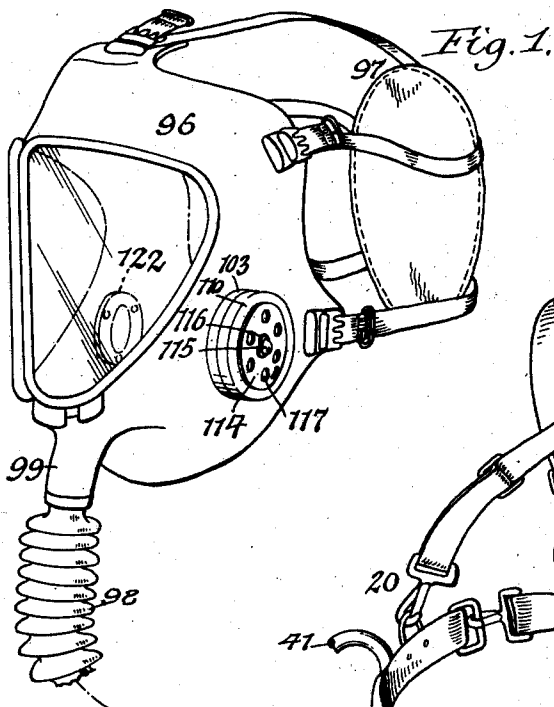
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2,406,888

BREATHING APPARATUS

Filed June 6, 1944

3 Sheets-Sheet 1



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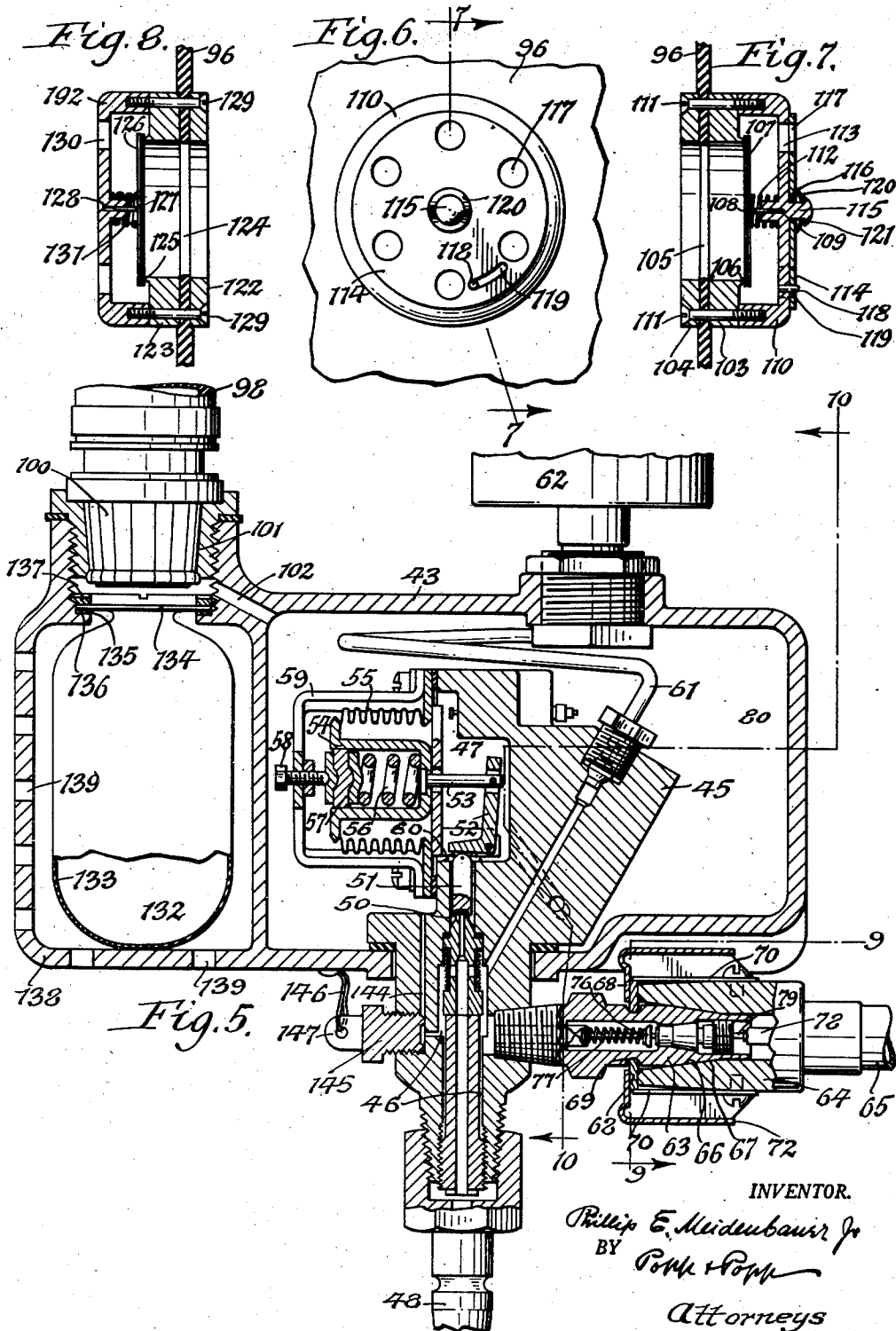
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2,406,888

BREATHING APPARATUS

Filed June 6, 1944

3 Sheets-Sheet 2



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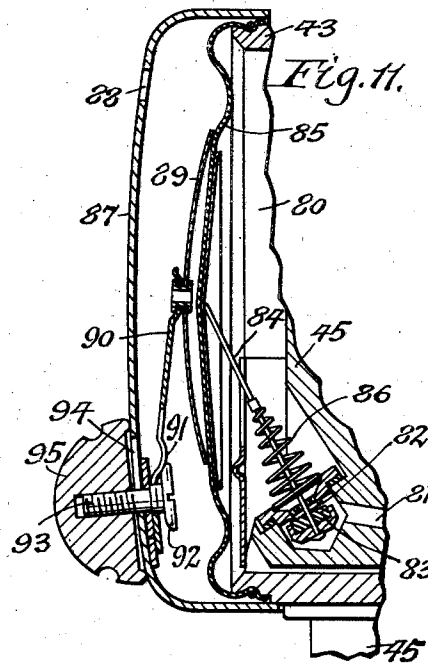
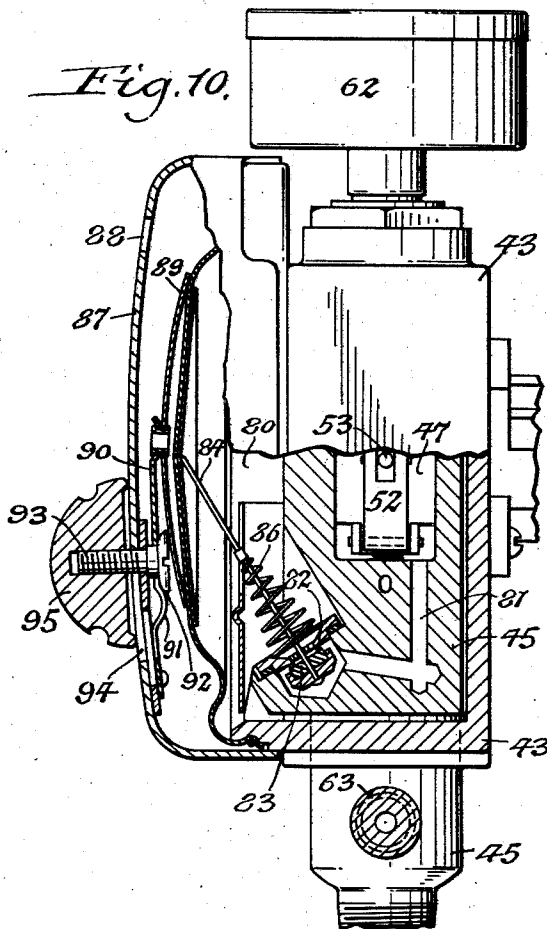
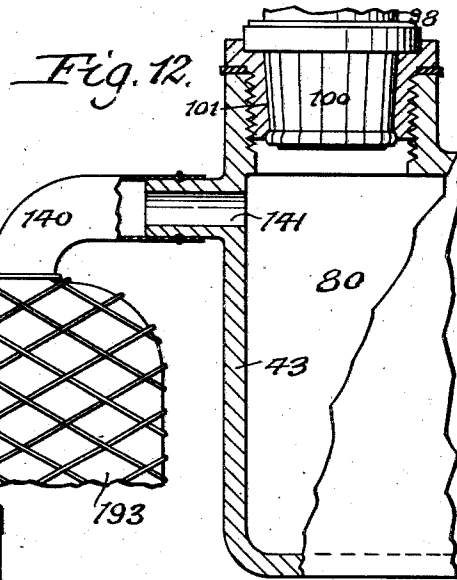
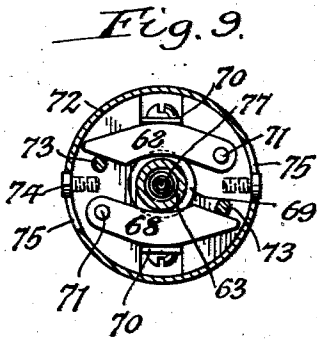
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BREATHING APPARATUS

Filed June 6, 1944

3 Sheets-Sheet 3



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2,406,888

BREATHING APPARATUS

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Application June 6, 1944, Serial No. 538,923

1 Claim. (Cl. 128—142)

1

This invention relates to a breathing apparatus and method of using the same which is more particularly designed for use by persons at or below ground level in mines or other such locations where, because of accident or for some other reason, the air is either full of explosive, poisonous or noxious vapors, or is contaminated with fine dust particles, or is deficient in oxygen content, or is at abnormally high pressure.

In order to enable a workman, operator or other person to enter any of such atmospheres or a combination thereof with safety it is desirable to utilize a portable breathing apparatus which prevents the wearer from being affected injuriously by any of these atmospheres.

It is the object of this invention to provide a simple, efficient and convenient apparatus for this purpose which can be readily carried by the person to be protected and easily and instantly operated in case of emergency to meet varying conditions and thus constantly safeguard the person using the apparatus.

In the accompanying drawings:

Fig. 1 is a perspective view of a mask embodying some of the features of this invention.

Fig. 2 is a similar view of the means for controlling the flow of air, gas or vapor to the mask in accordance with this invention.

Fig. 3 is a similar view of the storage means for carrying a supply of compressed air, oxygen or the like for use in this apparatus and embodying another feature of this invention.

Fig. 4 is a fragmentary sectional view showing a form of valve suitable for use in controlling the supply of compressed air, oxygen or the like to the apparatus when required in case of an emergency.

Fig. 5 is a vertical section of the means for controlling the flow of gas to the mask and associated parts.

Fig. 6 is a side view of a form of low resistance exhalation valve which is suitable for use in connection with the mask and capable of being rendered operative and inoperative at will.

Fig. 7 is a vertical section, taken on line 7—7, Fig. 6.

Fig. 8 is a vertical section of a high resistance exhalation valve adapted to be used in connection with the mask.

Fig. 9 is a cross section of a coupling for quickly connecting tubular members of this apparatus, this section being taken on line 9—9, Fig. 5.

Fig. 10 is a vertical section of the gas control mechanism of this apparatus, taken on line

2

10—10, Fig. 5 and showing more particularly the demand valve mechanism in a position in which the same will be opened and closed in response to the breathing of a person.

Fig. 11 is a similar view showing the demand valve held in its open position.

Fig. 12 is a fragmentary vertical section of a modified means for taking care of surging gas in this apparatus.

In the following description similar reference characters indicate like parts in the several figures of the drawings.

In its general organization this breathing apparatus comprises gas storage means from which air, oxygen or the like are supplied to the apparatus, control means whereby the flow of gas received from the storage means is controlled to suit requirements, and gas using or feeding means whereby live gas is delivered from the control means to the person using the apparatus and the spent gas is discharged to the atmosphere.

In the preferred form of the gas storage means the same, as shown in Figs. 3 and 4, are constructed as follows:

The numeral 20 represents the whole of a harness whereby gas storage means are supported on the body of a person and which includes a belt 21 adapted to pass around the waist of a person and suspenders 22 connected with the belt and passing over the shoulders of the person. In rear of the harness is arranged a sling or carrier whereby the gas containers are detachably mounted on the harness and which preferably comprises a comparatively wide flexible band 23 adapted to firmly and snugly receive the gas containers and having its central front part connected with the rear part of the harness and its opposed rear ends connected with each other by a lacing 24 passing through eyes 25 on the band and having its end tied together by a bow 26 in the manner of shoe strings. The gas container preferably comprises a plurality of containers, bottles or holders of relatively small diameter instead of a single bottle of large diameter inasmuch as a plurality of small bottles can be so arranged that the same comfortably straddle the spine of the person or worker and also project rearwardly a lesser distance. In the preferred construction shown in Fig. 3 two upright cylindrical front bottles or containers 27, 27 serve as the main storage means and are arranged transversely side by side within the band, and a third upright cylindrical rear bottle or container 28 which serves as auxiliary or emergency

3

storage means is nested between the rear parts of the front bottles, these bottles forming a cluster or group which is tightly held against movement within the sling band 23 and relative to each other by tightening the lacing 24 sufficient for this purpose. Each of the main bottles 27 is adapted to be filled with compressed air at a pressure of about 1000 lbs. per square inch and the small emergency bottle 28 is adapted to be filled either with compressed air at about 1800 lbs. per square inch pressure or the same may be filled with liquid or compressed oxygen while the large main bottles 27 are filled with compressed air.

Each of the main compressed air bottles 27 is provided at its lower end with a tubular neck through which the same is filled and emptied, this neck, while the apparatus is in use, being detachably connected by a "quick connect" coupling with a flexible branch delivery hose 30. This "quick connect" coupling consists generally of a tubular male plug 31 arranged on the neck 29 of the respective bottle and pushed into a female socket 32 of the respective branch hose 30.

Preparatory to mounting the main compressed air storage bottles 27 in the sling of the harness and using the breathing apparatus each of these bottles is removed from the sling and filled with compressed air by connecting its neck 29 temporarily with a main compressed air supply tank (not shown in the drawings), this being preferably accomplished by pushing the plug 31 of the "quick connect" coupling.

The auxiliary or emergency bottle 23 may be filled with the desired kind of compressed gas by screwing the tubular neck 33 at its lower end onto the pipe 34 of a storage tank containing a compressed supply of the gas desired.

Each of the main compressed air storage bottles 27 and the emergency compressed gas storage bottle 28 is provided at its upper end with a pressure gage 35 which enables the operator to determine whether the respective bottle contains air or gas at the required pressure.

The discharge of compressed air from the main compressed air storage bottles is controlled by the manually and automatically actuated controlling mechanism during normal operation of the apparatus in which case the main air supply bottles 27 contain sufficient air to adequately supply the requirements of usual conditions. Under normal conditions the outlet port 36 in the neck of the emergency bottle 28 is closed by an emergency valve which preferably has the form of a screw plug 37 having a threaded connection with the neck 33 so that upon screwing this plug tight the same will close the port 36 and shut off the escape of gas from the emergency bottle 28, as shown in Fig. 4. If, however, the supply of compressed air from the main bottles 27 is exhausted or deficient the operator unscrews the valve plug 37, thus opening the outlet of the emergency bottle and permitting the gas stored therein to be utilized in the apparatus. This emergency valve is preferably sealed or held against being turned into an open position by a sealing wire 38 which passes through an eye 39 on the outer end of the valve plug 37 and is soldered to the adjacent part of the neck 33, thereby preventing this valve from being opened accidentally and making it necessary for the operator to rip off the sealing wire 38 before this valve can be opened and permit the emergency supply

4

of compressed gas to enter the breathing apparatus and aid the operator.

The gas from the several storage bottles 27, 28 may be carried to the control mechanism in various ways, but preferably by the means shown in Fig. 3 in which these bottles are connected in parallel by means of a manifold or cross-shaped tubular fitting having four branches one of which is connected with the branch hose or tube 30 of one main compressed air storage bottle 27, the second of which is connected with the branch hose 30 of the other main compressed air storage bottle, the third of which is connected with the outlet neck 33 of the emergency compressed gas storage bottle 28, and the fourth of which connects with a main flexible gas or air delivery hose or tube 41 which leads to the gas control mechanism.

For convenience in using the breathing apparatus and keeping the main delivery hose from getting in the way, a part of this tube between the compressed air and gas storage bottles is supported on the harness preferably by arranging a part of this hose in a tube 42 formed on the belt 21 of the harness by stitching together a plurality of layers constituting a part of this belt, as shown in Fig. 3.

The controlling mechanism which is interposed between the compressed air or gas storage means and the means which feed this air or gas to the person using the apparatus include means which reduce the pressure of the air or gas from the high pressure at which it is stored in the bottles 27, 28 to a low pressure of about 0.75 inch of water at which the same can be fed to the person using the breathing apparatus.

Pressure reducing mechanism suitable for this purpose is disclosed in United States patent application Ser. No. 505,172 and is constructed and operated as follows:

The numeral 43 represents the case of a control mechanism which may be attached to and supported on the harness or any suitable part of the garment of the person using the apparatus by means of a clip 44. Within this case is arranged a body 45, the lower part of which contains a high pressure chamber 46 and the upper part of which contains a low pressure chamber 47. The outer end of the high pressure chamber is detachably connected by a "quick connect" coupling with the delivery hose 41 by a male tubular coupling plug 48 connected with the outer end of the high pressure chamber and pushed into a female socket 49 on the delivery hose 41. Communication between the high and low pressure chambers 46, 47 is controlled by a pressure reducing mechanism which is constructed as follows and shown in Figs. 2, 5, 10 and 11:

The numeral 50 represents a valve seat formed around the port between the high and low pressure chambers and 51 a reducing valve movable toward and from the seat for closing and opening said port. Within the low pressure chamber is arranged a bell crank or L-shaped lever 52 one arm of which bears against the inner end of the reducing valve 51 and the other arm of which is connected by a rod 53 with a head 54 which closes the movable end of a bellows 55. The fixed end of this bellows is secured to the body 45 and its interior communicates with the high pressure chamber so that the interior of the bellows is exposed to the same pressure which exists in the high pressure chamber. The head 54 of the bellows is subjected to the pressure of the spring 56 which tends to collapse the bellows

5

which spring bears at its outer end against a follower 57 the position of which may be adjusted by a pressure adjusting screw 58 for varying the effect of this spring. This adjusting screw 53 is mounted on a bracket 59 which is connected with the body 45.

When the pressure within the low pressure chamber has been reduced to the desired degree, the bellows are expanded and turn the bell crank lever 52 so that the same moves the reducing valve into its closed position, as shown in Fig. 5, thereby preventing the further admission of high pressure medium from the high pressure chamber into the low pressure chamber. When the pressure in the low pressure chamber drops below normal the return spring 55 contracts the bellows and turns the bell crank lever 52 with the aid of an auxiliary spring 60 and permits the reducing valve to open under the pressure existing in the high pressure chamber and thereby allows the air or gas under high pressure to flow from the high pressure chamber into the low pressure chamber. When the normal pressure has again been restored in the low pressure chamber the bellows expands and turns the bell crank lever in the direction for shutting the reducing valve and arresting the flow of pressure medium from the high pressure chamber into the low pressure chamber.

In order to enable the user of the breathing apparatus to readily observe the pressure in the high pressure chamber the latter is connected by a passage 61 with a pressure indicator 62 mounted on the top of the case where the same can be conveniently read.

If desired the high pressure chamber may be supplied directly with a main or large source of compressed air or gaseous medium instead of from the bottles 27, 28 which are of relatively small capacity. For this purpose the body 45 is provided externally of the case 43 with a "quick connect" coupling whereby the high pressure chamber 47 may be connected with a main low pressure source independently of the pressure storage bottles 27, 28. As shown in Figs. 2 and 5 this "quick connect" coupling comprises a tubular male coupling plug 63, pushed into a female coupling socket 64 forming part of a main hose or tube 65 which communicates with a main or large source of pressure medium. This plug 63 may also be used to simultaneously charge both bottles 27, 28.

Although the "quick connect" couplings 31, 32; 48, 49; and 63, 64 may be of any suitable construction that form shown in detail in Figs. 5 and 9 is preferred and constructed as follows:

The male member or plug of this "quick connect" coupling is provided with a conical periphery or tapering surface 66 and the bore 67 of the socket or female member of this coupling which is engaged by this conical periphery is of corresponding tapering or conical form, as shown in Fig. 5. As the plug 63 is pushed into the socket 64 the conical surface of the plug engages with two locking jaws 68 and spreads them and at the inner end of this movement these jaws contract and engage an annular groove 69 on the coupling plug whereby the plug and socket of the "quick connect" coupling are locked together. These jaws are pivoted by pins 71 to the socket member 64 and are yieldingly held in engagement with the groove 69 by springs 70 on the socket member 64. When it is desired to uncouple the plug and socket of the "quick connect" coupling, this may be effected by turning

6

a cup-shaped releasing sleeve 72 on the periphery of the coupling socket whereby releasing pins 73 on this sleeve are caused to spread the jaws 68 and disengage the same from the groove 69 of the coupling plug and thereby permit the latter and the coupling socket to be pulled apart. Rotation of the releasing sleeve is limited by a stop pin 74 on the releasing sleeve engaging with a circumferential slot 75 in this sleeve, as shown in Fig. 9.

A check valve, similar to air tire valves, is employed in connecting the members of each "quick connect" coupling so that when the members of the same are connected the passage between the same will be opened but when these members are separated backward flow through the male member will be shut off. The main elements of such a check valve shown in Fig. 5 include a closure member 76 which is yieldingly held in its closed position by a spring 77 and a releasing pin 78 arranged in the socket 64 of the coupling and operating against the stem 79 of the closure member for opening the check valve when the plug and socket of the "quick connect" coupling are pushed together.

The body 45 forming part of the flow control means is spaced from the case 43 to form an intermediate delivery or respiration chamber 80 which is adapted to receive low pressure breathing fluid from the low pressure chamber 47 and supply the same to the means which feed this fluid to the person using the apparatus as required. The flow of this breathing fluid from the low pressure chamber to the delivery chamber is controlled by demand valve means which are responsive to the breathing action of the person being supplied with the breathing fluid which demand valve means are similar to those shown in United States patent applications Serial Numbers 466,165 and 505,172 and are constructed as follows:

The numeral 81 is a fluid port or passage formed in the body 45 and extending from the low pressure chamber to the delivery chamber and having a rearwardly facing demand valve seat 82 at its outlet end, as shown in Figs. 10 and 11. This seat is adapted to be engaged by a rocking demand valve 83 for opening and closing the port 82 which is connected with the inner end of an inclined valve stem 84 projecting into the delivery chamber 80. The outer end of this valve stem engages with the inner side of a flexible diaphragm 85 which forms a part of the wall of the case 83 and has its outer side exposed to atmospheric pressure. Upon exhausting fluid from the delivery chamber by the inhalation of the person being served with this fluid, the diaphragm 85 is drawn inwardly and causes the valve stem 84 to rock the demand valve 83 into an open position, as shown in Fig. 11, thereby permitting the breathing fluid to flow from the low pressure chamber to the delivery chamber. When this inhalation ceases the demand valve is rocked back into its closed position by a spring 86 connected with this valve stem and resting of an adjacent relatively stationary support. Upon moving the demand valve into its closed position the spring 86 also moves the diaphragm outwardly into its expanded position, as indicated in Fig. 10.

For a purpose which will presently appear the demand valve 82 may be held constantly in its open position and thus permit the low pressure breathing fluid to flow from the low pressure chamber into the delivery chamber independ-

ently of the breathing action of the person being served. Means suitable for this purpose, shown in Figs. 2, 9 and 10, are similar to those shown in United States patent application Serial No. 505,172 and are constructed as follows:

The numeral 87 represents a cover applied to the case 43 over the outer side of the diaphragm and provided with openings 88 to permit the pressure of the atmosphere to act on the outer side of the diaphragm. The numeral 89 represents a bearing plate which engages with the outer side of the diaphragm and 90 a retaining arm having preferably the form of a leaf spring which has its inner free end connected with the bearing plate 89 while its outer end is connected with the cover 87. Means are provided for permitting the retaining arm 90 to either move inwardly for holding the diaphragm in its collapsed condition and the demand valve in its open position or permitting the diaphragm to expand and the demand valve to close. This is accomplished by a detent projection 91 arranged on the inner side of the retaining arm adjacent to its fixed end, a shifting head 92 movable lengthwise of said arm over said detent 91 and into a position on either side of the same, a shank 93 movable radially in a slot 94 in the cover 37 and carrying said head at its inner end, and a positive pressure knob or fingerpiece 95 arranged outside of the cover and connected with the outer end of said shank. Upon moving said shifting head 92 inwardly nearer the free end of the retaining arm 90 the latter will be held in its outwardly retracted position, as shown in Fig. 10, whereby the diaphragm is free to expand and the demand valve is free to close, but when this shifting head is moved nearer to the fixed end of the retaining arm 87, as shown in Fig. 11, this arm, due to its resilience, will move inwardly and hold the diaphragm in its contracted or collapsed condition and hold the demand valve in a tilted open position. Upon moving the shifting head 92 lengthwise of the retaining arm over the detent 91 in either direction, this detent will yieldingly hold the shifting head in its outer or inner position.

The means for feeding the breathing or sustaining fluid to the person being served may be variously constructed but usually includes a mask, the body 96 of which is applied to the face of the person and held on the head of the same by fastening means 97 similar to those shown in Fig. 1, or of any other suitable construction. The breathing fluid is conducted from the delivery or respiration chamber 69 to the interior of this mask by a service tube 98 which is preferably of corrugated form and permanently connected at its upper end with the inlet 99 at the front of the mask while its lower end is detachably connected with the respiration chamber by a "quick connect" coupling comprising a tubular plug 100 arranged at the lower end of the service tube 98 and adapted to be slipped into a tubular socket 101 arranged on the top of the case 43 and communicating by a passage 102 with the respiration chamber, as shown in Fig. 5.

Valve means are provided whereby the breathing fluid which is exhaled into the mask may be discharged from the latter to the atmosphere by encountering either practically no resistance or a substantial amount of resistance depending on the conditions under which the apparatus is being used. This is preferably accomplished by means of two exhalation valve units one of which, termed a primary or main exhalation valve unit,

opens under a low or nearly zero pressure in the mask for permitting the breath of exhalation to escape from the mask to the atmosphere but can also be rendered inoperative by manually actuated means so as to prevent escape of breathing fluid from the mask to the atmosphere, while the other, termed a secondary or auxiliary exhalation valve unit, only opens under a relatively high pressure in the mask before the breath of exhalation can escape to the atmosphere. The primary exhalation valve unit, as shown in Figs. 1, 6 and 7, is preferably constructed as follows:

The numerals 103, 104 represent outer and inner valve rings secured to the outer and inner sides of a part of one wall of the mask around an opening 105 therein forming together the primary exhalation port of this valve unit. The outer valve ring 103 is provided around the outer end of this port with a valve seat 106 and this port is opened and closed by a primary valve 107 which is movable toward and from the seat 106. This valve is guided by means of a stem 108 projecting outwardly from the central part thereof and sliding in a guideway 109 on the central part of a cap 110 which extends over the outer side of the primary exhalation valve and engages with the outer side of the outer valve ring 103. The latter, together with the inner valve ring 104 and the cap 110, are connected and secured to the mask by screws 111. The primary exhalation valve is yieldingly held in its inner closed position by a comparatively light spring 112 which surrounds the valve stem 108 and its guideway and is interposed between the primary exhalation valve and the cap 110, as shown in Fig. 7. Around its center the cap of the primary exhalation valve is provided with an annular row of openings 113 and on the outer side of this cap is rotatably mounted a disk-shaped shutter 114 which is pivoted on the cap by a pivot pin 115 projecting outwardly from the cap through a central bearing opening 116. This shutter is provided with an annular row of openings 117 which may be moved into and out of register with the openings 113 in the cap 110 by turning the shutter manually on the pin 115. Means for limiting the oscillation of the shutter in either direction and arresting the same when its openings are either in register or out of register with the openings in the cap is preferably effected by a stop pin 118 projecting forwardly from the cap into a segmental or arcuate slot 119 in the shutter, as shown in Figs. 6 and 7. The shutter disk is frictionally held against rotation by means of a spring 120 preferably of C-shape which is mounted on the pivot pin 115 and interposed between the outer side of the shutter and a shoulder 121 on this pin so that the tension of this spring presses this shutter against the outer side of the cap.

The secondary or auxiliary exhalation valve unit is constructed substantially like the primary exhalation valve unit with the exception of the shutter device and comprises outer and inner valve rings 122, 123 engaging the outer and inner sides of another part of the wall of the mask around an opening 124 therein and thus forming a secondary exhalation port, an outwardly facing secondary valve seat 125 formed on the outer side of the ring 123 around this port, a secondary exhalation valve 126 movable toward and from the valve seat 125 for closing and opening the secondary exhalation port, a guide pin 127 projecting outwardly from the secondary exhalation valve and sliding in a guideway 128 formed

in a cap 129 which extends across the outer side of the valve 126 and ring 123, screws 129 connecting the valve rings 123, 124 and the cap 132 with the respective wall of the mask, openings 130 formed in the cap 129 around its center, and a comparatively heavy spring 131 surrounding the guide pin 127 and guideway 128 and interposed between the cap 129 and the secondary valve 126 for holding the latter yielding in its inner closed position in engagement with the seat 125.

Whenever the worker inhales and draws fluid by a negative pressure from the delivery or respiration chamber 80 into the mask the pressure on the outer side of the diaphragm drops below atmospheric pressure whereby the demand valve 83 is opened and low pressure fluid is permitted to flow from the low pressure chamber 47 to the respiration chamber and replace that which has been drawn through the service tube 98 into the mask. Under normal conditions when the atmosphere is not contaminated, part of the fluid in the mask during exhalation of the person is discharged from the mask to the outer atmosphere through the port of the primary exhalation valve unit the valve disk 107 of which opens easily inasmuch as the resilient resistance to the light spring 112 to such opening is almost zero, but closes quickly when a negative pressure exists in the mask during inhaling and thus prevents any air outside of the mask from entering the mask.

When, however, the worker suspects the presence of poisonous or noxious substances in the atmosphere through which he is able to travel, he not only pushes down the positive pressure knob 95 so as to open the demand valve 83, as shown in Fig. 11, but he also turns the shutter 114 so as to close the shutter openings 113 and thus prevent the primary exhalation valve 107 from opening, thereby compelling the discharge of exhalation from the mask to the outer atmosphere through the secondary exhalation valve unit to take place under a higher resistance due to the heavier spring 131 which loads the secondary exhalation valve to such an extent that it only opens at a pressure of 1.25 inches of water which is slightly above the pressure of fluid, viz., 0.75 inch of water, as the fluid is discharged by the pressure regulator or reducer into the respiration chamber and mask connected therewith by the service tube 98. In other words, the worker, under these particular conditions inhales from a source which has a pressure of, say, 0.75 inch of water and hence drops the pressure in the mask to a point slightly below 0.75 inch of water. Then, when he exhales, he causes the pressure in the mask and in the corrugated hose or service tube 98 and connecting spaces to rise to, say, 1.25 inches of water, which pressure is sufficient to permit exhalation to be vented out from the mask to the outer atmosphere through the heavy spring loaded secondary exhalation valve 126.

From the foregoing it will be clear that during normal use of the apparatus the demand valve will be opened intermittently by negative pressure due to inhalation of the wearer which is satisfactory for breathing under safe conditions, but if the wearer believes that the atmosphere might be dangerously poisonous, noxious or injurious he naturally does not want any negative pressure in the mask, the service hose or other spaces communicating therewith, but instead wants a positive pressure in these spaces to insure a definite supply of life sustaining fluid to the wearer while there is a possibility of the

surrounding atmosphere being contaminated and it is at this time that the primary exhalation valve is shut off and the demand valve is held open so as to ensure a steady supply of life sustaining fluid to the wearer and prevent the same from escaping too freely to the atmosphere.

Experiments have shown that when a person is at rest while using this apparatus, approximately the first third of the volume of air or breath exhaled contains only slight traces of CO₂, the reason probably being that this third part of the air or breath which previously filled the mouth, thoracic ducts, bronchial tubes and the entrance of the lungs never reached the main area of the lungs from which the major part or bulk of CO₂ emanates and, furthermore, did not have time enough to absorb any considerable part of CO₂ from the breath which did go into the lungs. Means are therefore provided by this invention whereby this first one-third of each exhaled breath is prevented from venting out to the atmosphere through the exhalation valves, but is saved for use in connection with the next inhalation which means are constructed as follows:

At a point relatively close to the respiration chamber and the inlet end of the service hose 98 and remote from the mask a surge chamber or compartment 132 is provided which in effect is an enlargement of the passage between the respiration chamber and the mask and serves to take up any back pressure of air in this passage. In the preferred construction this surge chamber is formed in a bag 133 which is made of impervious but flexible and elastic material, such as rubber, which has a neck 134 communicating with the air service passage from the respiration chamber to the mask at a point relatively close to this chamber but remote from the mask. As shown in Fig. 5 the connection between the surge bag 133 is effected by detachably mounting the surge bag on the case 43 so that it communicates with the air service passage between the respiration chamber and the socket 101 which receives the "quick connect" coupling plug 100. The means for thus detachably mounting the surge bag on the case comprise a collar 134 secured to the neck of this bag and resting by means of an interposed soft packing ring 135 on an annular shoulder 136 on the case and a clamping ring 137 having a screw connection with the case and bearing against the front or upper side of the collar 134.

When the worker is inhaling, a partial vacuum is created in the service hose 98 and in the respiration chamber and spaces communicating therewith. When the worker starts the next following exhalation the pressure in the mask, service hose and the respiration chamber is increased, but at first this increased pressure is not enough to open either of the exhalation valves. While this pressure is being built up, some of the exhaled air flows backwardly into the surge bag 133 and builds up an appreciable amount of pressure therein. When the worker again inhales the pressure in the mask, service hose and respiration chamber, as well as in the surge bag, is again lowered, thereby causing the air stored in the surge bag to flow out and join the stream of air which is flowing from the respiration chamber to the mask before the demand valve is opened. This insures that all the air inhaled is well loaded with CO₂ before it is exhaled from the mask and thereby enables the worker to use the apparatus a longer time before he is compelled to come back

11

to the source of supply of compressed fresh air to refill his portable bottles or containers.

Owing to the surge bag being closely connected with the respiration chamber and remotely connected with the mask, the first third of the exhalation of the worker which is only slightly contaminated with CO₂ does not pass into the surge bag but is received almost wholly within the mask and the service hose and is thereafter swept into the very bottom or remote part of the lungs during the next inhalation, thereby always keeping the surge bag free from CO₂. At the end of each inhalation all parts of this apparatus are free from contaminated air, particularly the mask and service hose which are close to the face of the wearer. It will now be apparent that the first third, or substantially so, of the breath which is exhaled by the person using the apparatus is that which contains the lowest percentage of CO₂ and it is this partly vitiated or contaminated air which is sent down to the very deepest part of the lungs on the next inhalation and thus charged to the maximum extent with CO₂ and is then the last part of the air to be exhaled and hence is inevitably discharged to the outer atmosphere through one or both exhalation valves which open at this time under the increased pressure exerted against them at this time, while none of this air is directed toward the surge bag because the latter is only filled as a consequence of the backward flow of the first third of the exhaled air.

When the user of this apparatus exhales the virtually uncontaminated air from the thorax, bronchial tubes, etc., the same enters the mask before enough pressure has been built up therein to open the exhalation valves and service hose, thereby causing a pressure to be built up in the surge bag. During the subsequent inhalation fluid flows from the surge bag and respiration chamber before the demand valve opens, which ensures that all the air which is fully inhaled will be well loaded with CO₂ before it is discharged from the mask to the outer atmosphere and thus enables the worker to use the apparatus a longer time before he is compelled to refill the portable containers from a main supply source. By thus saving the first third of the worker's exhaled breath, both when he is resting and when he is doing physical work, the length of time he can keep going without recharging the air storage bottles or tanks is increased one-third, or for the same length of time, the size of the bottles or tanks may be reduced one-third.

If desired the surge chamber may be formed in a metal can or other container having fixed walls but this is disadvantageous owing to the capacity being constant and permits of storing therein a volume of air equal to the difference between the pressure of the air flow into and out of such a can, whereas a flexible bag when collapsed can receive its full volume of air at a pressure which balances the atmospheric pressure, and can receive, in addition, the same volume of air which a metal can is capable of storing.

By utilizing a bag which is not only flexible but also elastic as a surge chamber the same is merely distended and collapsed or contracted, but not stretched when used while the worker is at rest. When, however, the worker does physical work, then both the volumes and positive and negative pressures of his inhalation and exhalation are increased under which circumstances the bag not only collapses, as would a bag which is only flexible and not stretchable,

12

but the same is also capable of increased capacity due to its stretchability, thereby enabling the same to hold approximately one-third greater volume of air.

In order to prevent too great a distention of the elastic surge bag and possible bursting of the same, limiting means are provided which operate to arrest the further expansion of the surge bag after the same has expanded to a predetermined extent. Various means may be employed for this purpose. For example, as shown in Fig. 5, this is accomplished by a guard or stop wall 138 which preferably is formed integrally with the case and encloses the surge bag like a cage and is provided with vent openings 139 so that the exterior of the surge bag is exposed to atmospheric pressure. When the surge bag has been distended by the pressure of the air within the same until it engages the limiting wall 138 further distention is prevented and thus avoids injury to the same.

Instead of employing a separate surge bag as a unit separate from the case 43 it is to be understood that the volume of the respiration or delivery chamber 80 may be made sufficiently large, as shown in Fig. 5, to also form an inflexible surge tank which will take care of the first third of the air exhaled by the worker while resting or while doing physical work, and, if desired, this surge bag may be arranged in a suitable compartment within the respiration chamber instead of on the outer side of the same.

An alternative form of means for taking care of the first one-third of the exhalation of the worker is shown in Fig. 12 in which a flexible and elastic surge bag 193 is arranged on one side of the respiration chamber 80 of the case and provided with a tubular neck 140 which is connected with a coupling tube 141 projecting from the side of the case and places the respiration chamber in communication with this surge bag. Expansion or distention of the surge bag in this modified form of this feature of the invention is limited by an inelastic netting or open mesh sack 142 which encloses the surge bag 193.

Safety means are provided whereby compressed air may be conducted directly from the high pressure source of air to the service hose and mask regardless of the pressure reducing or regulating means or the demand valve mechanism in case of an emergency, such as might occur if the pressure reducing means and the demand valve means, or either of them, should become defective or fail to operate efficiently or cease to function altogether. Means for this purpose are shown in Fig. 5 and include a safety or emergency bypass 144 formed in the body 45 and extending from the high pressure air chamber 46 to the respiration chamber 80 and a safety valve having preferably the form of a plug 145 which has a screw connection with the body 45 so that upon turning this plug in one direction the same will obstruct or close the bypass 144 and prevent the flow of high pressure air directly to the mask while upon turning this plug in the opposite direction this bypass is opened and permits high pressure air to pass from its source directly to the mask through the medium of the service hose, thereby avoiding endangering the worker for the want of uncontaminated air. As a precaution to prevent this safety valve from being opened except in case of an emergency the same is sealed in its closed position by a soft lead retaining or sealing wire 146 which passes through an eye 147 on the outer end of the screw plug

13

valve and is soldered to the adjacent part of the case. Whenever the occasion requires it the worker breaks the sealing wire by hand and then turns this plug valve into its open position and thus permits air to reach the mask without being subjected to the operation of the regulating valve and demand valve, or either of them.

I claim as my invention:

A breathing apparatus, comprising a high pressure fluid chamber adapted to receive sustaining fluid from a high pressure source, a low pressure chamber which receives fluid at reduced pressure from said high pressure chamber, a respiration chamber which receives fluid from said low pressure chamber, a mask which communicates with said respiration chamber and whereby sustaining fluid is supplied to a person, exhalation valve means through which fluid is discharged

14

from the mask and which comprises one unit having a lightly loaded outwardly opening check valve member and another unit having a heavily loaded outwardly opening check valve member, manually operated means for positively holding said lightly loaded check valve member in its closed position, pressure regulating valve means interposed between said high and low pressure chambers, demand valve means interposed between said low pressure chamber and said respiration chamber and adapted to be opened in response to inhalation of the person using the apparatus, and manually operated retaining means for holding the demand valve means in open position and bypassing said pressure regulating valve means.

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